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Validation of snow depth reconstruction from lapse-rate webcam images against terrestrial laser scanner measurements in centrel Pyrenees

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Snow distribution in mountain areas plays a key role in many processes as runoff dynamics, ecological cycles or erosion rates. Nevertheless, the acquisition of high resolution snow depth data (SD) in space-time is a complex task that needs the application of remote sensing techniques as Terrestrial Laser Scanning (TLS). Such kind of techniques requires intense field work for obtaining high quality snowpack evolution during a specific time period. Combining TLS data with other remote sensing techniques (satellite images, photogrammetry...) and in-situ measurements could represent an improvement of the available information of a variable with rapid topographic changes.

The aim of this study is to reconstruct daily SD distribution from lapse-rate images from a webcam and data from two to three TLS acquisitions during the snow melting periods of 2012, 2013 and 2014. This information is obtained at Izas Experimental catchment in Central Spanish Pyrenees; a catchment of 33ha, with an elevation ranging from 2050 to 2350m a.s.l. The lapse-rate images provide the Snow Covered Area (SCA) evolution at the study site, while TLS allows obtaining high resolution information of SD distribution.

With ground control points, lapse-rate images are georrectified and their information is rasterized into a 1-meter resolution Digital Elevation Model. Subsequently, for each snow season, the Melt-Out Date (MOD) of each pixel is obtained. The reconstruction increases the estimated SD lose for each time step (day) in a distributed manner; starting the reconstruction for each grid cell at the MOD (note the reverse time evolution). To do so, the reconstruction has been previously adjusted in time and space as follows. Firstly, the degree day factor (SD lose/positive average temperatures) is calculated from the information measured at an automatic weather station (AWS) located in the catchment. Afterwards, comparing the SD lose at the AWS during a specific time period (i.e. between two TLS acquisitions) to that melted on each grid cell, a coefficient is obtained for spatially distributing the SD loses.

For 2012 and 2013, three TLS acquisition campaigns were available during each melting period. This way the first acquisitions of both melting periods were reserved for validation while the other two were considered for adjusting the reconstruction. Validation has revealed a very good performance of the reconstructed SD distribution when compared with the TLS data (r2 values between 0.74 and 0.8 respectively). When no calibration with TLS data was applied for distributing melt rates; this is, using the distribution coefficients for reconstructing SD of precedent years, rather similar accuracy was reached. With the spatial calibration of 2012 and 2013, the reconstructions for the two TLS acquisition dates in 2014, obtained r2 values that ranged between 0.73 and 0.76. This shows the usefulness of lapse-rate images to estimate not only SCA but also the spatial distribution of the SD when combined with TLS acquisition and punctual information on temperature and SD. In such a way it is shown the effectiveness of combining two remote sensing techniques for obtaining distributed information on snow depth.